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Otey et al.

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(54) **INTEGRATED THERMOELECTRIC-POWERED FLUID HEAT EXCHANGER**

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H01L 35/30	(2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***H01L 35/30*** (2013.01); *F28D 1/024* (2013.01); *F28D 7/0008* (2013.01); *F28F 3/025* (2013.01); *F28F 5/00* (2013.01)

(58) **Field of Classification Search**
CPC F28F 5/00; F25B 21/02
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,726,193 A * 2/1988 Burke F25B 21/02
62/354
2002/0134087 A1 9/2002 Urch
(Continued)

FOREIGN PATENT DOCUMENTS

JP	07-104113 B2	11/1995
WO	2012-061777 A2	5/2012

OTHER PUBLICATIONS

PCT International Search Report and Written Opinion, PCT/US2014/056353, dated Jun. 12, 2015.

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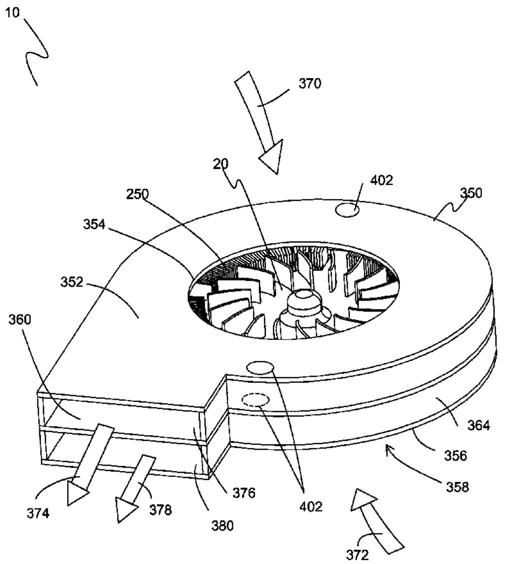
(57) **ABSTRACT**

A fluid heat exchanger has an impeller assembly with first and second impeller bodies mated together, each having a substantially circular shape and at least one opening therethrough. Impeller vanes extend transversely from the first impeller body and away from the second impeller body. Impeller vanes extend transversely from the second impeller body away from the first impeller body. A thermoelectric module is disposed between the first impeller body and the second impeller body. Heat sinks are connected to each side of the thermoelectric module and extend through at least one opening in the first and second impeller bodies, where the impeller vanes are configured to move a fluid through the heat sinks during rotation of the first and second impeller bodies. Electrically-conductive windings disposed in the impeller assembly are configured to deliver induced electric current to the one or more thermoelectric modules.

13 Claims, 6 Drawing Sheets



(51) **Int. Cl.**

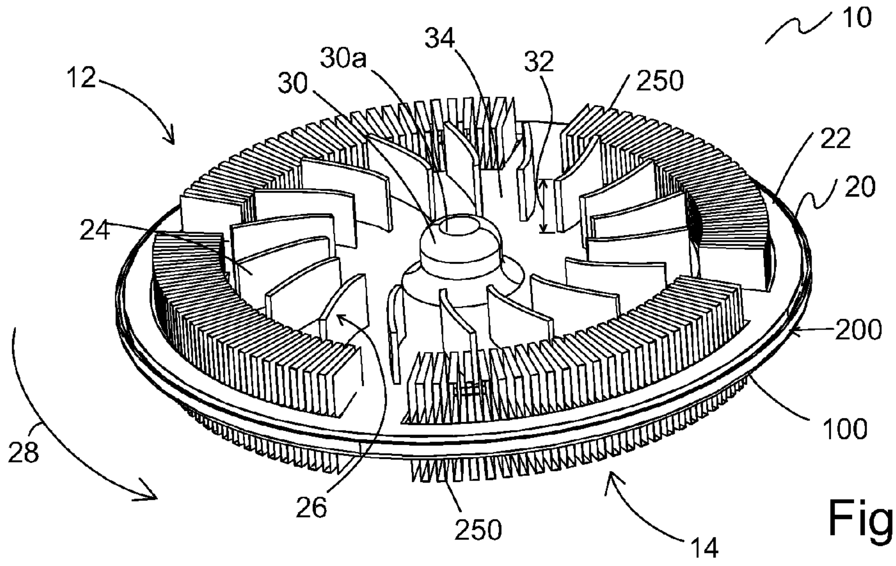
F28F 5/00	(2006.01)
F28D 7/00	(2006.01)
F28D 1/02	(2006.01)
F28F 3/02	(2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0054745	A1*	3/2008	Sentmanat	A61M 1/101 310/89
2009/0026813	A1	1/2009	Lofy	
2009/0034202	A1	2/2009	Chiu et al.	
2011/0259386	A1*	10/2011	Lee	F24J 2/06 136/206

* cited by examiner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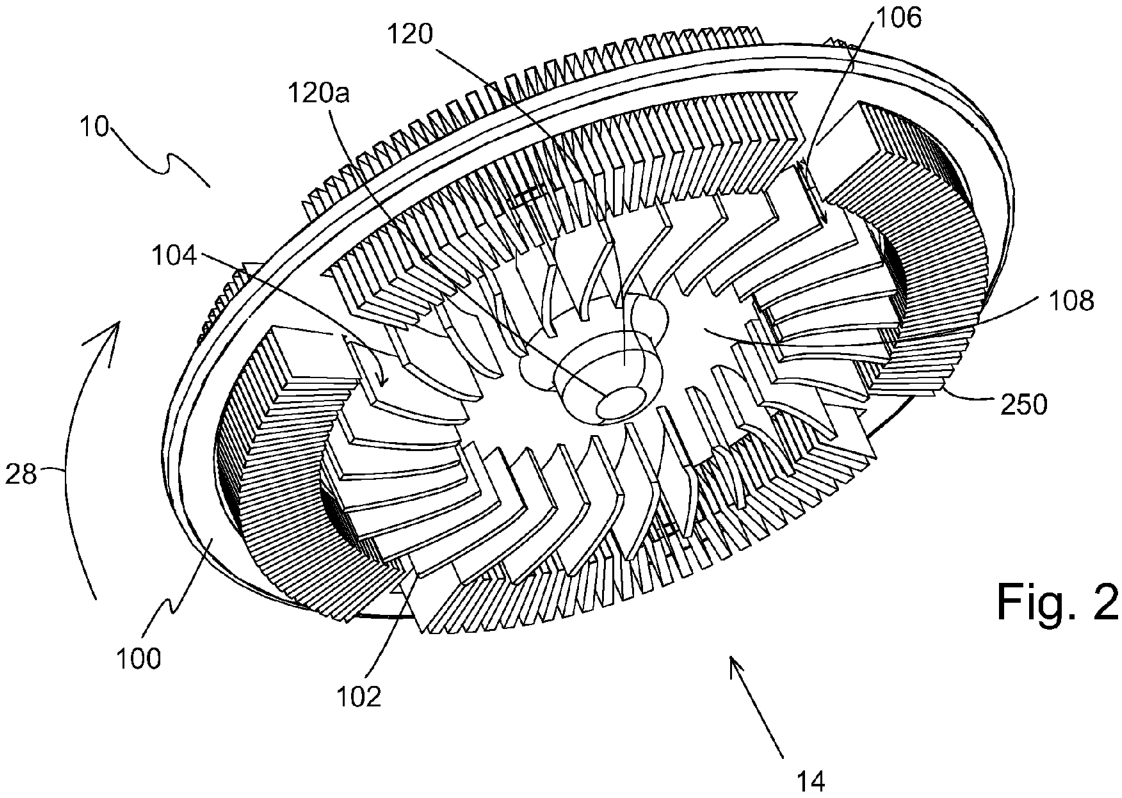
12
30a
34
32
250
30
22
20
24
200
28
100
26
250
14

Fig. 1


120
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120a
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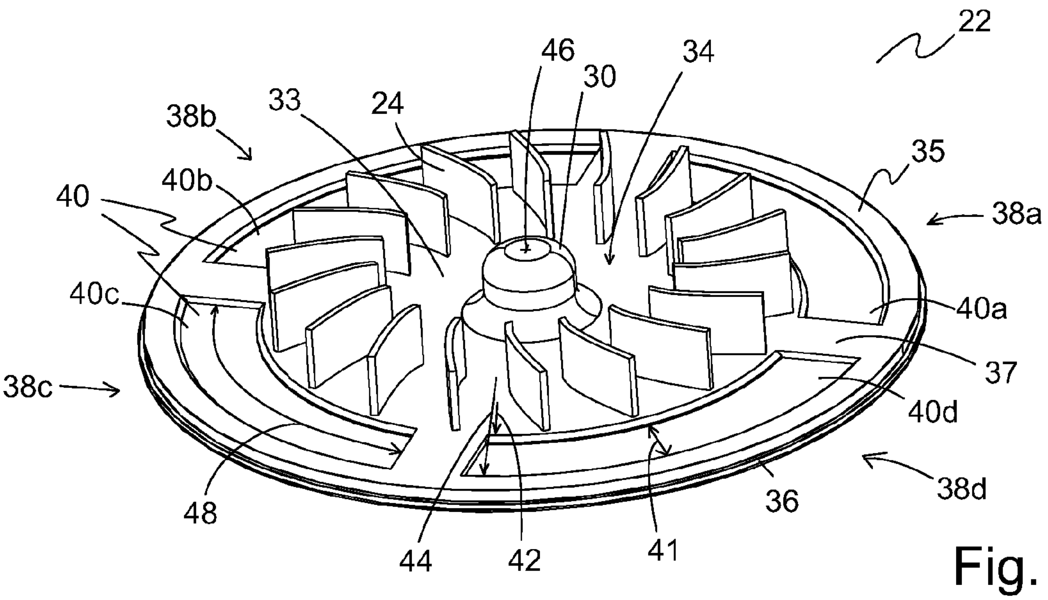
104
108
250
28
100
102
14

Fig. 2


22
46
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34
38b
33
24
35
40b
40
38a
40c
40a
37
38c
40d
38d
36
48
44
42
41

Fig. 3

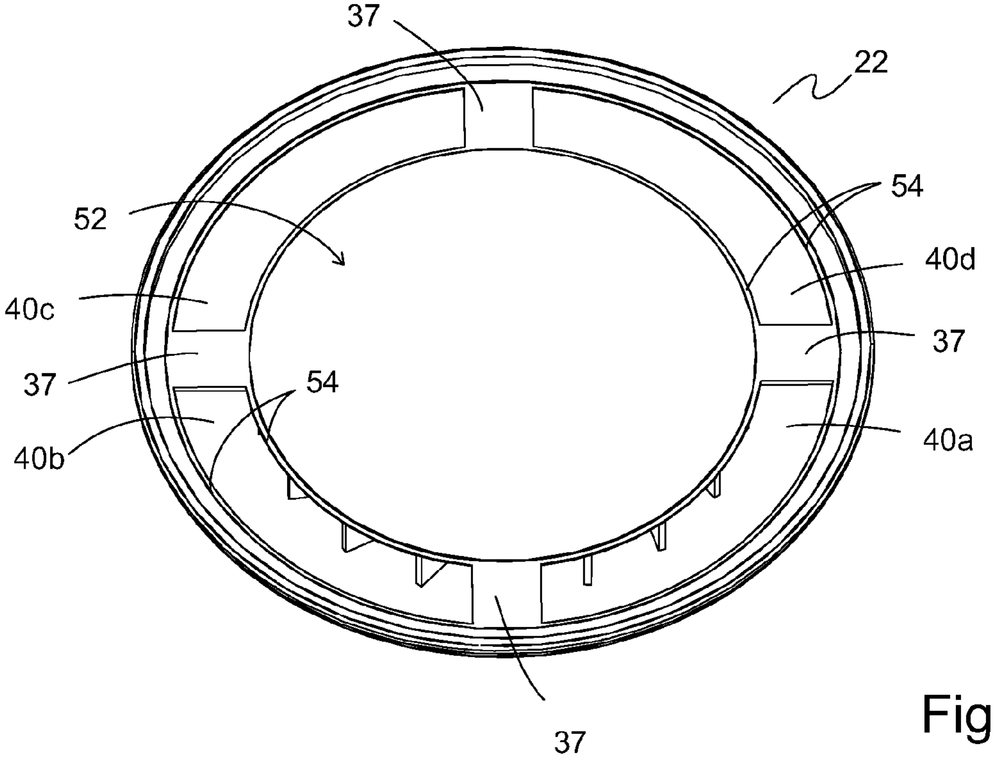
37
22
54
52
40d
40c
37
37
54
40b
40a
37

Fig. 4

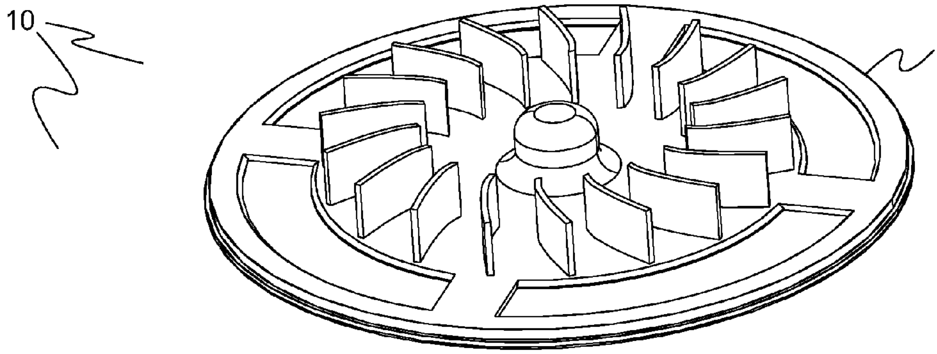

Fig. 5

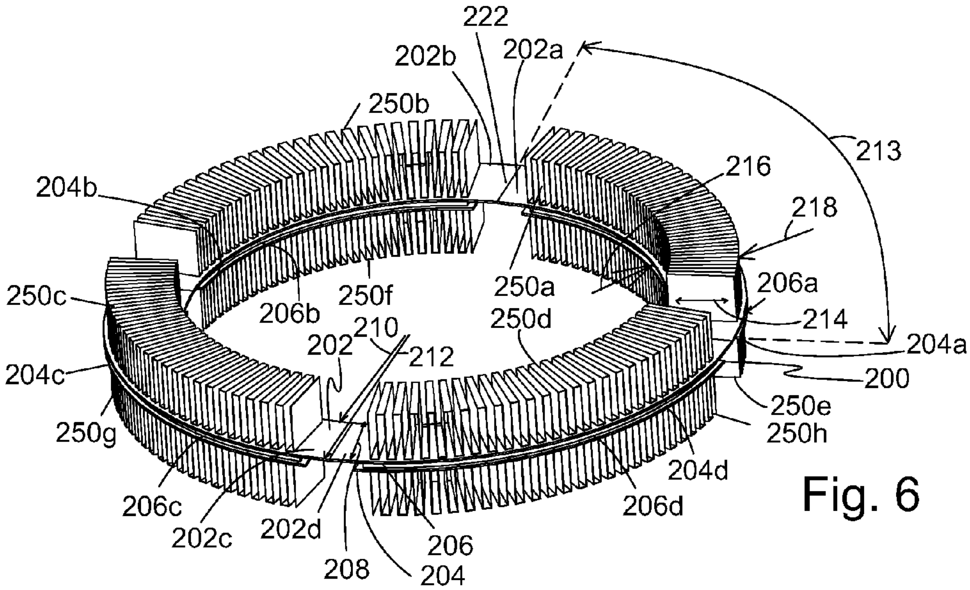

Fig. 6

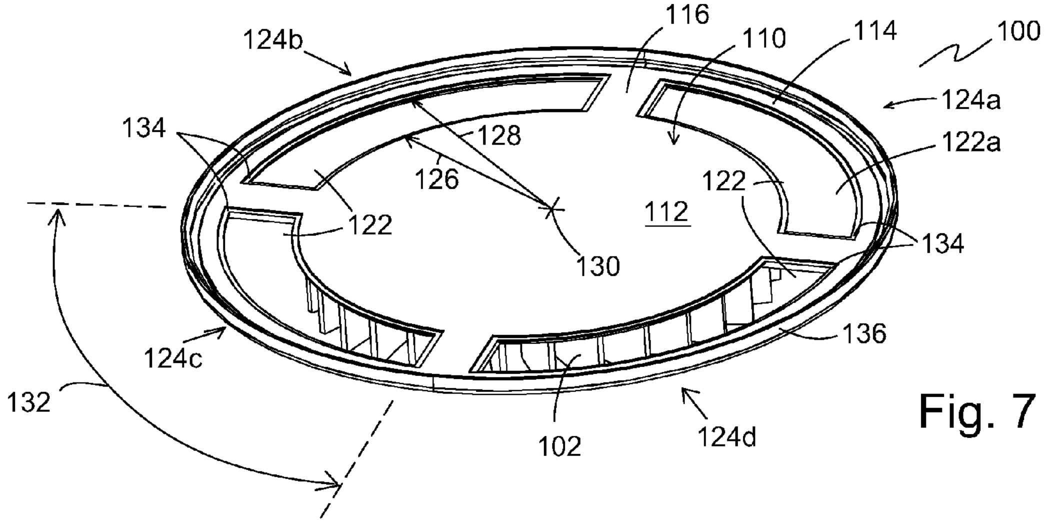

Fig. 7

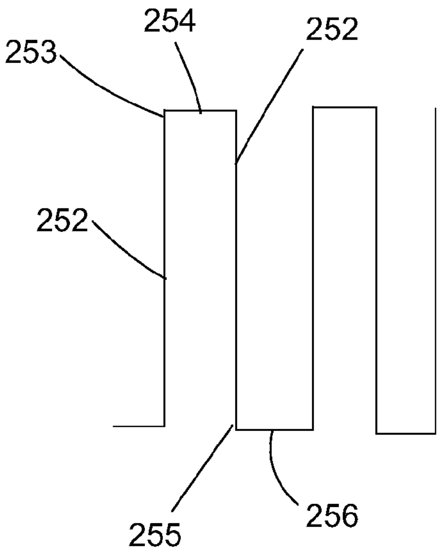

Fig. 6A

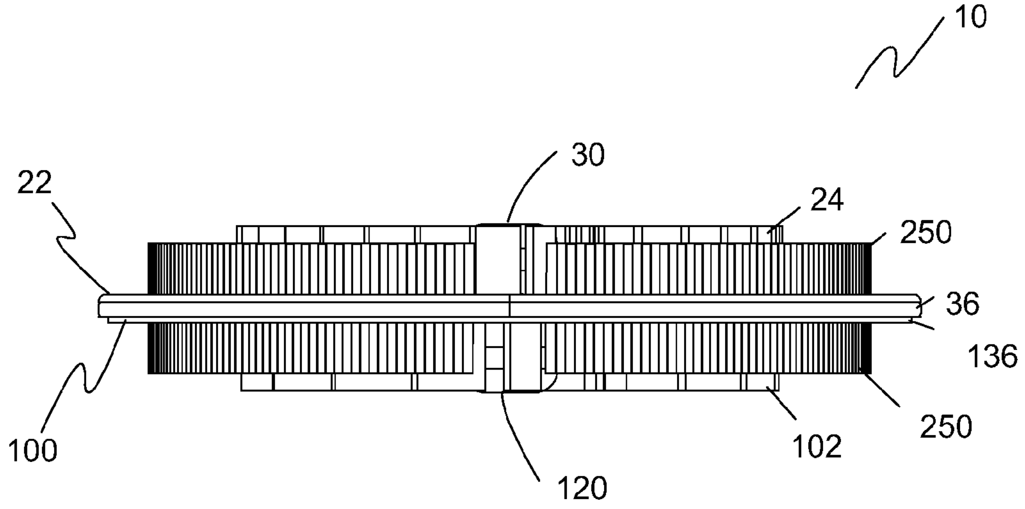

Fig. 8

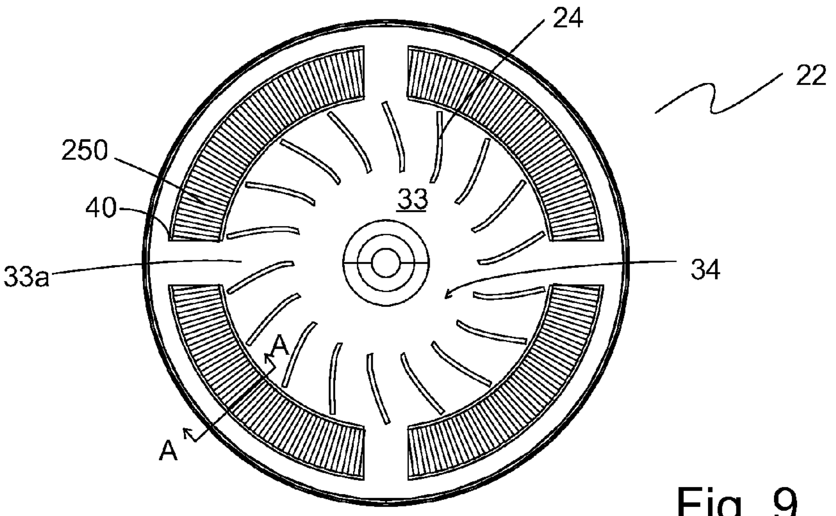
24
22
250
40
33
33a
34
A
A

Fig. 9

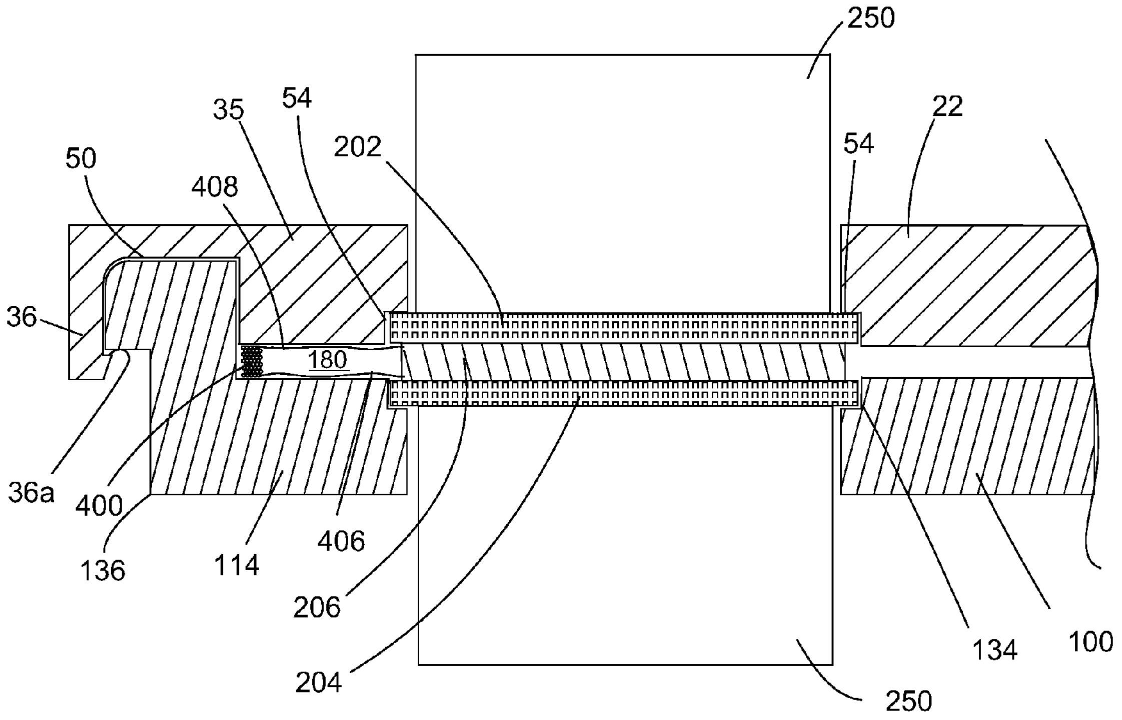
250
35
54
202
54
22
50
408
36
180
36a
400
136
114
406
206
204
134
100
250

Fig. 10

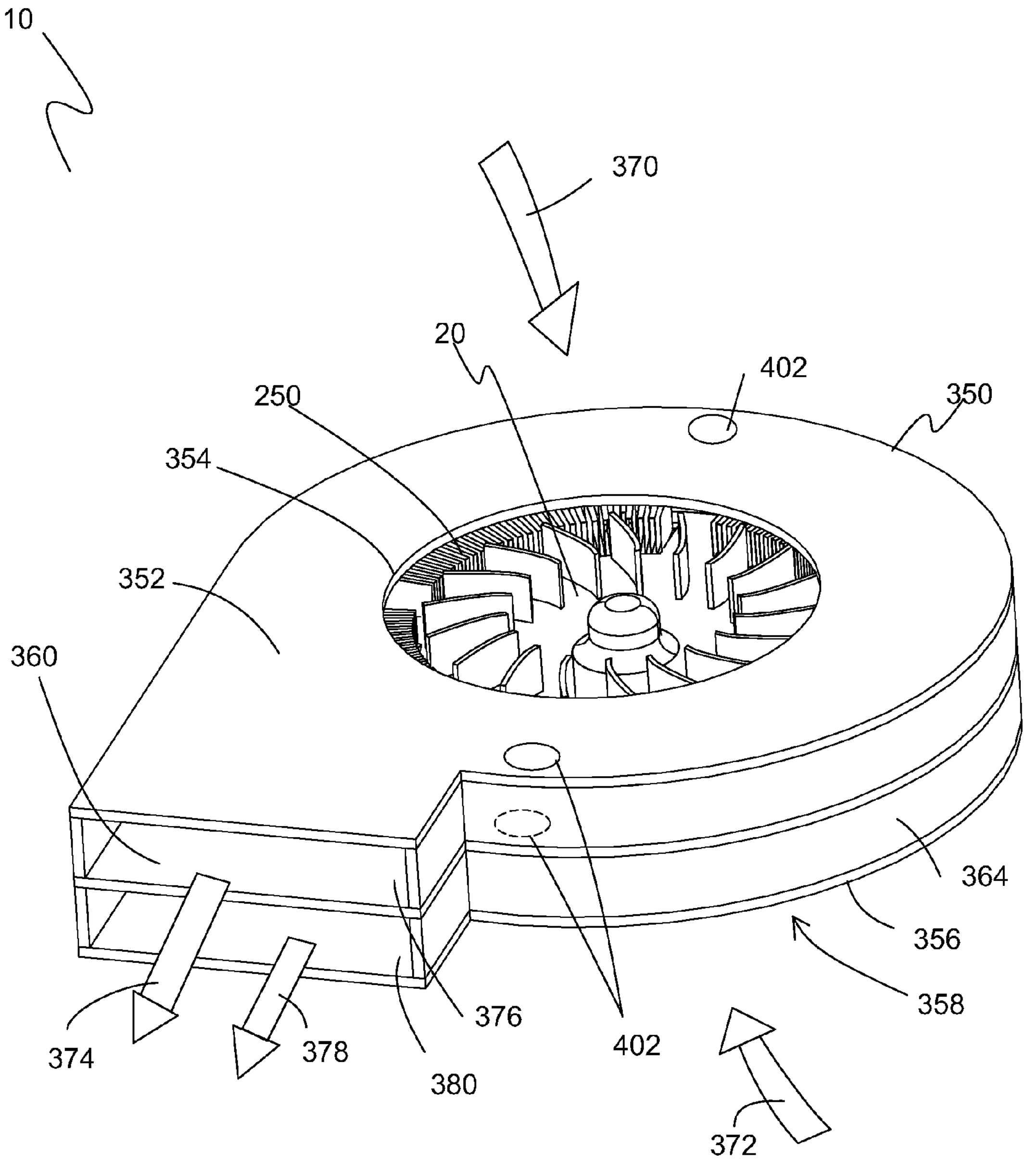
10
370
20
402
350
250
354
352
360
364
356
358
376
402
374
378
380
372

Fig. 11

INTEGRATED THERMOELECTRIC-POWERED FLUID HEAT EXCHANGER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to thermoelectric devices and more particularly to an integrated thermoelectric-powered fluid heat exchanger.

2. Description of the Prior Art

A thermoelectric (TE) module, also called a thermoelectric cooler or Peltier cooler, is a semiconductor-based electronic component that functions as a heat pump. By applying low-voltage DC power to a TE module, heat is transferred through the module from one side to the other. One module face, therefore, is cooled while the opposite face is simultaneously heated. This phenomenon may be reversed by changing the polarity of the applied DC voltage. As a result, heat is transferred in the opposite direction. Consequently, a thermoelectric module may be used for both heating and cooling, making it suitable to precisely control temperature.

In practice, a thermoelectric module generally consists of two or more elements of n-type and p-type doped semiconductor material (e.g., bismuth telluride) that are connected electrically in series and connected thermally in parallel. These thermoelectric elements and their electrical interconnects typically are mounted between two ceramic substrates. The substrates hold the overall structure together mechanically and electrically insulate the individual elements from one another and from external mounting surfaces. Thermoelectric modules have a size of up to 300×300 mm (12×12 inches) and a height or thickness of 0.5 to 5 mm (0.02 to 0.2 inches). A variety of different shapes, substrate materials, metallization patterns and mounting options are available.

Thermoelectric modules are typically used in fluid heat exchangers as a stationary device where heat sinks or separate thermal transport devices are situated with the thermoelectric module. A blower, fan, pump, or the like provides a fluid supply stream used in transferring heat between the heat sinks and the fluids.

In a typical configuration, power is supplied to a thermoelectric module from a separate power source. In rotating devices where hard wiring is not possible due to rotation, power is commonly supplied through commutators or slip rings in contact with rotating conductors. Rotating conductors (either slip rings or commutator segments) are added to the rotating shaft and include stationary carbon brushes to transfer the power. In other variations, the brushes rotate in contact with stationary conductors.

SUMMARY OF THE INVENTION

The above-described configurations have problems and deficiencies upon which the present invention improves. A typical configuration with a thermoelectric module includes many parts, is constrained by size, and is limited by the availability of fluid supplies.

In traditional rotating devices, where power is supplied to the rotating device by commutators or slip rings, the rotation speed is limited due to heat from friction. Also, rotation causes wear to contacts and requires maintenance, such as checking for wear and or replacing brushes. Cleanliness and contamination is also a problem due to particles generated by friction between moving parts.

Therefore, what is needed is a fluid heat exchanger that reduces or eliminates moving electrical connectors and reduces contamination to the surroundings.

It is an object of the present invention to integrate a thermoelectric heat exchanger and fluid mover in a single assembly.

It is another object of the present invention to improve the reliability of fluid heat exchangers.

It is another object of the present invention to deliver induced electric power to a thermoelectric module.

The present invention achieves these and other objectives by providing a single assembly that integrates a thermoelectric module, heat sinks, and a fluid mover or impeller. In one embodiment of the present invention, a fluid heat exchanger has an impeller assembly that includes first and second impeller bodies, each having a substantially circular shape and a plurality of openings therethrough. The second impeller body is disposed substantially parallel and connected to the first impeller body. Impeller vanes extend transversely from the first impeller body and away from the second impeller body. Impeller vanes extend transversely from the second impeller body away from the first impeller body. A thermoelectric module with a first substrate and a second substrate is disposed between the first impeller body and the second impeller body. Electrically-conductive windings disposed in the impeller assembly are configured to deliver induced electric current to the one or more thermoelectric modules. Heat sinks connected to the first substrate and to the second substrate and extend through respective openings in the first and second impeller bodies, where the impeller vanes are configured to move a fluid through the heat sinks during rotation of the first and second impeller bodies.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of one embodiment of a fluid heat exchanger of the present invention showing a first side.

FIG. **2** is a perspective view of the fluid heat exchanger of FIG. **1** showing a second side.

FIG. **3** is a perspective view of a impeller body of the present invention showing an outside surface with impeller vanes.

FIG. **4** is a perspective view of the impeller body of FIG. **3** showing an inside surface.

FIG. **5** is a perspective view of the impeller body of FIG. **3** shown as part of an exploded assembly with a thermoelectric module and second impeller body.

FIG. **6** is a perspective view of a thermoelectric module with heat sinks of the present invention shown as part of an exploded assembly.

FIG. **6**A is a front view of one embodiment of a heat sink.

FIG. **7** is a perspective view of a second impeller body of the present invention showing an inside surface and as part of an exploded assembly.

FIG. **8** is a side view of the fluid heat exchanger of FIG. **1**.

FIG. **9** is a plan view of the fluid heat exchanger of FIG. **1**.

FIG. **10** is a side cross-sectional view through line A-A of FIG. **9** showing assembly of the fluid heat exchanger of FIG. **1**.

FIG. **11** is a perspective view of the fluid heat exchanger of the present invention shown within a housing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiments of the present invention are illustrated in FIGS. **1-11**. FIG. **1** illustrates a perspective view of one embodiment of a fluid heat exchanger **10** of the present invention. Fluid heat exchanger **10** includes a fluid mover assembly or impeller assembly **20** and a thermoelectric module **200** (shown in FIG. **6**) with a plurality of heat sinks **250**. This embodiment integrates thermoelectric module **200**, impeller assembly **20**, and heat sinks **250** as a single assembled unit that is configured to rotate on a shaft (not shown) that extends into or through an aperture **30***a* in hub **30**.

One or more thermoelectric module(s) **200** is (are) sandwiched between a first impeller body **22** and a second impeller body **100**. A plurality of heat sinks **250** are attached to or formed integrally with each thermoelectric module **200**, preferably with at least one heat sink **250** on a first side **202** and on a second side **204** of thermoelectric module **200** (shown in FIG. **4** and discussed below).

First impeller body **22** has a plurality of first impeller vanes **24** attached to or extending from first impeller body in a substantially perpendicular direction. In one embodiment, first impeller body **22** has eighteen first impeller vanes **24**. Other quantities may be selected as appropriate for the desired fluid flow and heat transfer effect. In one embodiment, each impeller vane **24** has a concave face **26** that preferably faces in the direction of rotation **28** to more efficiently move a fluid, such as air, through or across heat sink(s) **250**. In one embodiment, first impeller vanes **24** have a height **32** that exceeds that of heat sink(s) **250** beyond a planar surface **34** of first impeller body **22**.

Referring now to FIG. **2**, a perspective view illustrates one embodiment of a second side **14** of fluid heat exchanger **10**. Similar to first impeller body **22**, second impeller body **100** has a plurality of second impeller vanes **102** attached to or extending from second impeller body **100** in a substantially perpendicular direction. In one embodiment, second impeller body **100** has thirty second impeller vanes **102**. Other quantities may be selected as appropriate for the desired fluid flow and heat transfer effect. In one embodiment, each impeller vane **102** has a concave face **104** that preferably faces in direction of rotation **28** to more efficiently move a fluid, such as air, through or across heat sink(s) **250**. In one embodiment, second impeller vanes **102** have a height **106** that exceeds that of heat sink(s) **250** beyond a planar surface **108** of second impeller body **100**. In other embodiments, second impeller vanes **102** have height **106** that is the same or lesser than the height of heat sink(s) **250**. Second impeller body **100** has a second hub **120** with second aperture **120***a* to receive a shaft (not shown). In some embodiments, aperture **30***a* of hub **30** is continuous with second aperture **120***a* of second hub **120**. It is contemplated that first and second impeller bodies **22**, **100** may have a different number of impeller vanes **22**, **102** on each side or an equal number of vanes and the above-listed number of vanes is not intended to be limiting. In other embodiments, impeller vanes **24**, **102** have height **32**, **106**, respectively, that is the same or lesser than the height of the heat sink(s) **250**. It is also understood that the impeller vane may have any shape so long as it transverse to the impeller body and provides air movement across heat sinks **250**. It is further understood that the impeller vanes may vary in height.

Referring now to FIG. **3**, there is illustrated a top, perspective view of first impeller body **22** with hub **30** and first impeller vanes **24**. First impeller body **22** is generally planar with an outside surface **34**. First impeller body **22** has an inner region **33** of generally circular shape connected to an outer ring **35** by bridge segments **37** extending radially between inner region **33** and outer ring **35**. Outer ring **35** has an overhanging first impeller perimeter rim **36** that extends in a direction (e.g., downward) opposite of first impeller vanes **24** (e.g., upward). First impeller body **22** has a plurality of first body openings **40**, preferably arc-shaped, and bounded by first inner region **33**, first bridge segments **37**, and first outer ring **35**. It is contemplated that bridge segments **37** may be narrower or wider than shown relative to the openings **40**, or may be eliminated entirely with modification to the mating of first and second impeller bodies **22**, **102**.

In one embodiment, first impeller body **22** has four openings **40***a*-**40***d* with one first body opening **40** disposed in each of four quadrants **38***a*-**38***d* of planar surface **34**, with even angular spacing between four bridge segments **37**. Each of openings **40***a*-**40***d* preferably extends between a first radius **42** and a second radius **44** from center **46** of outside surface **34** and has an arc width **48** of about eighty degrees. Openings **40***a*-**40***d* are sized and configured to allow heat sinks **250** to extend therethrough. In other embodiments, more or fewer first body openings **40** may be used, such as a plurality of substantially square or rectangular first body openings **40** evenly spaced around first impeller body **22** for receiving substantially square or rectangular thermoelectric modules **200**.

Referring now to FIG. **4**, a perspective view is shown of inside surface **52** of first impeller body **22**. A ring-shaped first substrate recess **54** is disposed on inside surface **52** and enclosing openings **40***a*-**40***d* and bridge segments **37**. First substrate recess **54** is sized and configured to receive first substrate **202** of thermoelectric module **200**, which is discussed below with reference to FIG. **6**. Inside surface **52** optionally includes one or more additional features useful for attaching first impeller body **22** to second impeller body **100**. These additional features include, for example, a locking ring, fastener openings, fastener posts, standoff posts or members, and structures known in the art for snap-fit engagement between first impeller body **22** and second impeller body **100**. These optional features may similarly be included on inside surface **110** of second impeller body **100**, which is discussed below. Standoff posts or members may be strategically placed to provide additional strength to the thermoelectric module **200**.

FIGS. **5**, **6**, and **7** as a group illustrate an exploded, perspective view of components of fluid heat exchanger **10** with first impeller body **22**, thermoelectric module **200** with heat sinks **250**, and second impeller body **100**. First impeller body **22** was discussed above.

Referring now to FIG. **6**, a perspective view shows one embodiment of thermoelectric module **200** with heat sinks **250**. The assembly of four thermoelectric modules **200** forms a substantially annular shape with a semiconductor layer **206** disposed between a first substrate **202** and a second substrate **204** of each thermoelectric module **200**. In other words, each thermoelectric module **200** defines an arc. Semiconductor layer **206** comprises a plurality of n-type and p-type semiconducting materials that are electrically connected in series. For example, adjacent n-type and p-type materials are connected with copper connectors and forming a planar array of n-p and p-n junctions. First substrate **202** and second substrate **204** each connect to opposite sides of semiconducting layer **206** to structurally hold together the plurality of n-p and p-n junctions. First substrate **202** and second substrate **204** also transfer heat from semiconducting layer **206** to heat sinks **250**. First substrate **202** and second substrate **204** preferably are made of electrically-insulating materials and, preferably thermally conductive materials, such as a ceramic, epoxy, polyimide, etc. As illustrated, there is a space **222** between the heat sinks **250** coinciding with the bridge elements **37**. Space **222** may optionally include blocking members (not shown) to block the flow of air through space **222**. An advantage of including optional blocking members in space **222** would be to cause all air flow to be conditioned.

First substrate **202** includes four arc-shaped portions **202***a*-**202***d*. Second substrate **204** includes four distinct arc-shaped portions **204***a*-**204***d* that are shorter in length compared to arc-shaped portions **202***a*-**202***d* in this embodiment to provide space for electrical connections. More or fewer portions may be used in each of first substrate **202** and second substrate **204**. Like second substrate **204**, semiconducting layer **206** has four distinct regions or portions **206***a*-**206***d* disposed between substrates **202***a* & **204***a*, **202***b* & **204***b*, **202***c* & **204***c*, **202***d* & **204***d*, respectively.

In one embodiment, first substrate **202** and second substrate have equal radial widths **208** between a third (inner) radius **210** and a fourth (outer) radius **212**. Second substrate portions **204***a*-**204***d* have a substrate arc length **213** spanning about eighty degrees. Semiconducting layer portions **206***a*-**206***d* each have a third radial width **214** between a fifth (inner) radius **216** and a sixth (outer) radius **218**, where the fifth radius is equal to or greater than third radius **210** and sixth radius **218** is equal to or less than fourth radius **212**. Portions **206***a*-**206***d* of semiconducting layer **206** have a semiconducting arc length **220** equal to or less than substrate arc length **213**. Accordingly, each portion **206***a*-**206***d* of semiconducting layer **206** is positioned within the boundary of each portion **204***a*-**204***d* of second substrate **204**, respectively. It is contemplated that the substrates may be equal in size and configuration with the electrical connections recessed from the perimeters of both substrates within the thermoelectric module.

Heat sink **250** has four heat sink portions **250***a*-**250***d*, one for each portion **202***a*-**202***d* of first substrate **202**, respectively, and an additional four heat sink portions **250***e*-**250***h* on portions **204***a*-**204***d* of second substrate **204**. As shown in FIG. **6**A, for example, each heat sink portion **250***a*-**250***h* of heat sink **250** in one embodiment is a folded metal strip substantially having the shape of a repeating square wave with adjacent vertical portions **252** connected to a first horizontal portion **254** at a first end **253** and a second horizontal portion **256** at a second end **255**. Other forms of heat sink(s) **250** are acceptable, such as a heat sink (not shown) having a plurality of fins or protrusions extending from a base plate and made by metal injection molding or other methods known in the art. Although shown as having planar sides, heat sink **250** may also be shaped in a curved format much like an impeller.

Heat sink(s) **250** are adhered or connected to first substrate **202** and second substrate **204** of the thermoelectric module **200** using thermally-conductive adhesives, solder, or brazing. The method used to adhere thermoelectric module(s) **200** to head exchanger(s) **250** depends on the appropriate surface of first substrate **202** and second substrate **204**. For example, a copper laminate or metalized ceramic substrate may be used with soldering or brazing. Heat sink(s) **250** or other heat transfer components may also be integrally formed with or mechanically connected to first substrate **202** and/or second substrate **204**.

Referring now to FIG. **7**, a perspective illustration shows an inside surface view of one embodiment of second impeller body **100**. Like first impeller body **22**, second impeller body **100** has a second inner region **112** of generally circular shape and a second outer ring **114** connected to second inner region **112** by a plurality of second bridge segments **116**. Second impeller body **22** has a plurality of second body openings **122**, preferably with one opening **12** disposed in each of four quadrants **124***a*-**124***d*, having even angular spacing between second bridge segments **116**, and aligned with the first body openings **40** of first impeller body **22**. Each second body opening **122** preferably extends between a seventh (inner) radius **126** and an eighth (outer) radius**128** from a center **130** of second impeller body **100**. Seventh radius **126** and eighth radius **128** are preferably the same as first radius **42** and second radius **44**, respectively, of first impeller body **22**. Preferably, each second body opening **122** has a second arc width **132** spanning about eighty degrees. Second openings **122** are sized and configured to allow heat sink(s) **250**, such as **250***e-h*, to extend therethrough. Like first impeller body **22**, more or fewer second body openings **122** may be used in second impeller body **100**.

Surrounding each second opening **122** is a substrate recess **134** sized to receive second substrates **204**. As assembled, edges of each second substrate **204** occupy a substrate recess **134** with the attached heat sink **250** extending through second opening **122**. Bridge segments **37** of first impeller body and second bridge segments **116** of second impeller body are spaced from first substrate **202** to compensate for thermal expansion of thermoelectric module **200**. Recesses **134** are useful to prevent thermoelectric module **200** from rotating with respect to second impeller body **100** (and also first impeller body **22**). In embodiments where second substrates **204** extend to approach but spaced from one another to compensate for thermal expansion of thermoelectric module **200** or where recesses **134** are not a structural feature of the impeller body, other structures such as clips, fasteners, or protrusions may optionally be added to prevent rotation of thermoelectric module **200** from rotating with respect to impeller assembly **20**. Second impeller body **100** has a plurality of second impeller vanes **102** extending from outside surface **108** (not visible). A second hub **120** is disposed on outside surface **108**, preferably at center **130** of second impeller body **100**. Second outer ring **114** has a second impeller perimeter rim **136** extending in an opposite direction (e.g., upward) from impeller vanes **102** (e.g., extending downward).

Referring now to FIG. **8**, a side view illustrates one embodiment of fluid heat exchanger **10**. In one embodiment as illustrated, first impeller perimeter rim **36** of first impeller body **22** is shaped and configured to overlap, engage, and/or lock with second impeller perimeter rim **136** of second impeller body **100** to connect first impeller body **22** to second impeller body **100**. Heat sinks **250** extend through first impeller body **22** and through second impeller body **100**. First impeller vanes **24** extend from first impeller body beyond heat sink **250** and second impeller vanes **102** extend from second impeller body extend beyond heat sink **250**. First hub **30** and second hub **120** extend transversely to the plane of first and second impeller bodies **2**, **100** and are preferably flush with impeller vanes **24**, **102**, respectively.

Referring now to FIG. **9**, a plan view illustrates one embodiment of fluid heat exchanger **10** as viewed from a first side **12**. First impeller vanes **24** extend from outside surface **34** of inner region **33** and are disposed towards a radially outward portion **33***a* of inner region **33**, preferably proximate openings **40** and heat sinks **250**.

Referring now to FIG. **10**, a cross-sectional view taken along line A-A of FIG. **9** illustrates portions of first impeller body **22**, second impeller body **100**, and thermoelectric module **200** with heat sinks **250**. First substrate **202** is received in first substrate recess **54** of first impeller body **22**. Second substrate **204** is received in recess **134** of second impeller body **100**. Semiconducting layer **206** is positioned in a gap **180** between first impeller body **22** and second impeller body **100**. Perimeter rim **36** of first impeller body **22** and second perimeter rim **136** of second impeller body **100** overlap, interlock, or meet one another and are configured to define gap **180**. Gap **180** preferably extends between substantial portions of first and second impeller bodies **22**, **100**. In one embodiment, perimeter rim **36** extends transversely (e.g., downward) from outer ring **35** of first impeller body and defines a slot or recess **50** sized to receive second perimeter rim **136**. Second perimeter rim **136** extends transversely (e.g., upward) from second outer ring **114** and fits into recess **50**. Optionally, first perimeter rim **36** has a catch **36***a* that engages second perimeter rim **136** to lock together first impeller body **22** and second impeller body **100**.

The induced power is generated by induced current through current carrying conductors or wire windings **400** in gap **180** between first impeller body **22** and second impeller body **100**. In one embodiment, wire windings **400** are disposed in outer ring **35** of first impeller body and or second outer ring **114** of second impeller body. Electrical connections **406**, **408** are made to thermoelectric module **200** by passing conductors through gap **180** between first impeller body **22** and second impeller body **100**. A magnetic field is supplied by pole pieces **402** (shown in FIG. **11**), which are discussed below with reference to FIG. **11**.

Referring now to FIG. **11**, there is illustrated fluid heat exchanger **10** within a housing **350**. Housing **350** has a first side panel **352** with first side panel opening **354**, a second side panel **356** with second side panel opening **358** (not visible), a flow divider panel **360** with divider opening **362** (not visible), and a sidewall **364** extending between and connecting first side panel **352**, second side panel **356**, and flow divider panel **360**. Flow divider panel **360** is preferably aligned with perimeter rim **36** (shown in FIG. **3**) and second perimeter rim **136** (shown in FIG. **7**) to separate first fluid stream **370** (e.g., cooled fluid) and second fluid stream **372** (e.g., warmed fluid). Preferably, divider opening **362** is sized just larger than impeller assembly **20** to minimize mixing of first fluid stream **370** and second fluid stream **372**.

In another embodiment (not shown), housing **350** has a first portion that includes first side panel and part of sidewall **364** and a second portion that includes second side panel **356** with a second part of sidewall **364**. First portion and second portion join together along mating portions of sidewall **364** and define a slot or groove to receive flow divider panel **360**.

Housing **350** is designed to allow a first fluid stream **370** to be taken in through first side panel opening **354** and a second fluid stream **372** to be taken in through second side panel opening **358**. Each side of impeller assembly **20** creates a differential pressure that results in fluid moving across heat sinks **250** and flowing as a first exhaust stream **374** through first outlet **376** and as a second exhaust stream **378** through second outlet **380**. Thus, fluid heat exchanger **10** is suitable for cooling sensitive electronic enclosures, computer boxes, cooler bins, refrigerator boxes, cabinets, or hermetically sealed or clean systems. Fluid heat exchanger **10** may also be used to direct a conditioned fluid source (e.g., first flow stream **370**) to a load while diverting waste heat away from the load. This device is also suitable for use as an integral part of a closed loop heat exchanger system. When thermoelectric module **200** is powered, the fluid moving across the heat sinks is either heated or cooled depending on the polarity of the supplied voltage.

In another embodiment, heat sinks **250** are configured as impeller vanes **24** and/or **102** or are connected to impeller vanes **24** and/or **102** to increase heat transfer. Using heat sinks **250** as impeller vanes reduces the pressure drop and efficiency losses associated with standard thermoelectric devices with heat sinks. The result is that more fluid flows to the intended recipient. Impeller assembly **20** of the present invention introduces both a main fluid stream (e.g., first fluid stream **370**) and a waste fluid stream (e.g., second fluid stream **372**) into the same relatively compact, dual-sided rotating impeller. This design further increases fluid flow by providing two individual fluid streams as compared to a single fluid supply being split between a main fluid stream (e.g., cold side) and waste side fluid stream (e.g., hot side). This increased fluid flow results in greater overall heat transfer. Compared to prior art designs, the construction techniques of fluid heat exchanger **10** eliminate many of the cost and reliability issues in addition to improved performance. It is noted that designating the cold side as the main stream and the hot side as the waste stream is not limiting. Depending on the preferred application, the hot side may be the main fluid stream.

Fluid heat exchanger **10** rotates on a shaft or shafts (not shown) connected to or extending through hub **30** and second hub **120** and driven by a motor or other prime mover. A brushless motor (not shown) may optionally be used with fluid heat exchanger **10** as necessary. It is anticipated that most applications will use a separate prime mover to simplify design.

A magnetic field is provided by pole pieces **402** disposed in housing **350**. Magnetic flux can be supplied from small permanent magnets or through wound pole pieces where the flux strength is controlled by a variable field excitation current. In one embodiment, pole pieces **402** are disposed on or in flow divider panel **360**, which is adjacent to perimeter rim **36** and second perimeter rim **136**. In one embodiment, pole pieces **402** are disposed along an edge of divider opening **362** of flow divider panel **364**. Pole pieces **402** are alternately disposed in housing **350** or outside of housing **350**, depending on design parameters and constraints. For example, wire windings **400** may optionally be positioned on the impeller assembly **20** above the heat sinks **250**. Additionally, wire windings **400** may be positioned in multiple positions on impeller assembly **20** to provide multiple sources of induced power. Wire windings **400** in impeller assembly **20**, which is coupled to thermoelectric module through a rectifier **404** (not shown), are typically placed in gap **180** between outer ring **35** and/or second outer ring **114** and in close proximity to pole pieces **402**. As wire winding **400** moves through the magnetic field, a current is induced in the conductor and power is supplied to thermoelectric module **200**. The amount of current applied will depend on the number of windings, rotation speed and strength of the magnetic field.

Impeller assembly **20** may be made from a variety of materials that include plastics, conductive plastics, aluminum, steel or any other material suitable for the specific application. For high volume and lower cost, the preferred material, of first impeller body **22** and second impeller body **40** is injection-molded plastic. Other applications may benefit from material substitutions depending on fluid, performance, and cost considerations.

It is contemplated that the figuration of the number of impeller vanes and/or fins depends on the application. If the fluid heat exchanger **10** were configured to have the same number of impeller vanes on both sides of the impeller bodies, then the impeller vanes would push the same amount of air through both sides depending on downstream configuration. However, if one wanted the air as cool as much as possible and flow volume was not an issue, then a lesser number of vanes would be placed on the cold side of the fluid heat exchanger. The hot side would receive more airflow than the cooling side. The more cooling the hot side receives, the lower the temperature the cold side can achieve. The lower air flow across the cold side will allow more time for heat transfer and the cold air temperature will decrease.

Although the preferred embodiments of the present invention have been described herein, the above description is merely illustrative. Further modification of the invention herein disclosed will occur to those skilled in the respective arts and all such modifications are deemed to be within the scope of the invention as defined by the appended claims.

What is claimed is:

1. An integrated fluid heat exchanger comprising:

an impeller assembly comprising:

a first impeller body with a circular shape and having a first impeller perimeter rim and a plurality of first body openings therethrough;

a second impeller body disposed parallel and coaxial to the first impeller body, the second impeller body having a circular shape and a second impeller perimeter rim connected to the first impeller perimeter rim and a plurality of second body openings therethrough that coincides with the plurality of first body openings of the first impeller body;

a plurality of first impeller vanes extending transversely from the first impeller body and away from the second impeller body; and

a plurality of second impeller vanes extending transversely from the second impeller body and away from the first impeller body;

at least one thermoelectric module disposed between the first impeller body and the second impeller body, the at least one thermoelectric module having:

a first substrate and a second substrate;

a first heat sink connected to the first substrate and extending through the at least first opening; and

a second heat sink connected to the second substrate and extending through the at least second opening; and

a plurality of electrically-conductive windings disposed in the impeller assembly, the plurality of conductive windings configured to move through a magnetic field to thereby induce an electric current and to deliver the electric current to the at least one thermoelectric module;

wherein the at least one thermoelectric module is positioned annularly between an outermost perimeter of the first impeller body and the second impeller body, and the plurality of first impeller vanes and the plurality of second impeller vanes.

2. The integrated fluid heat exchanger of claim **1** wherein the components thereof are integrated within a single housing, such that the at least one thermoelectric module, the plurality of first impeller vanes and the plurality of second impeller vanes are integrated in a single assembly capable of rotating about a hub.

3. The integrated fluid heat exchanger of claim **1** wherein the plurality of first body openings in the first impeller body are congruent and parallel to the plurality of second body openings in the second impeller body, the plurality of first body openings and the plurality of second body openings being arcuately arranged.

4. The integrated fluid heat exchanger of claim **1** further comprising a hub having an aperture which is congruent with an aperture extending through a center of the first impeller body and an aperture extending through a center of the second impeller body.

5. The integrated fluid heat exchanger of claim **1** further comprising a hub; and each of the first heat sink, the second heat sink, the plurality of first impeller vanes and the plurality of second impeller vanes are arcuately arranged so as to radiate away from the hub.

6. The integrated fluid heat exchanger of claim **1** wherein the plurality of second impeller vanes have a height that is at least a height of the second heat sink.

7. The integrated fluid heat exchanger of claim **1** wherein the plurality of first impeller vanes have a height that is at least a height of the first heat sink.

8. The integrated fluid heat exchanger of claim **1** wherein the plurality of second impeller vanes have a height that is less than a height of the second heat sink.

9. The integrated fluid heat exchanger of claim **1** wherein the plurality of first impeller vanes have a height that is less than a height of the first heat sink.

10. The integrated fluid heat exchanger of claim **1** wherein:

the first impeller body further comprises a first planar outer surface, and a first inner region connected to a first outer ring by first bridge segments, the first bridge segments extend from the first inner region radially outward to the first outer ring; and

the second impeller body further comprises a second planar outer surface, and a second inner region connected to a second outer ring by second bridge segments, the second bridge segments extend from the second inner region radially outward to the second outer ring.

11. The integrated fluid heat exchanger of claim **10** wherein:

the first impeller body comprises the plurality of first body openings bounded by the first inner region, first bridge segments, and first outer ring;

the second impeller body comprises the plurality of second body openings bounded by the second inner region, second bridge segments, and second outer ring;

the first planer outer surface and the second planar outer surface are disposed axially opposed from one another; and

the first inner region and the second inner region are congruent with one another, and the first bridge segments and the second bridge segments are congruent with one another, such that the plurality of first body openings are congruent with the plurality of second body openings.

12. The integrated fluid heat exchanger of claim **1** wherein

the first impeller perimeter rim extends axially in a direction opposite of the first plurality of impeller vanes;

the second impeller perimeter rim extends axially in a direction opposite of the second plurality of impeller vanes;

the second impeller perimeter rim extends further than the first impeller perimeter rim such that a gap is defined between substantial portions of the first impeller body and the second impeller body; and

the first impeller perimeter rim and the second impeller perimeter rim interlock with one another, thereby connecting the first impeller body and the second impeller body to one another.

13. The integrated fluid heat exchanger of claim **1** further comprising a housing, the housing having: a first side panel with a first side panel opening,

a second side panel with second side panel opening,

a flow divider panel with divider opening, and

a sidewall extending between and connecting each of the first side panel, the second side panel, and the flow divider panel.

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